Peter Hehenberger · David Bradley
Editors

Mechatronic Futures

Challenges and Solutions for Mechatronic Systems and their Designers

Springer

Mechatronic Futures

Peter Hehenberger · David Bradley
Editors

Mechatronic Futures

Challenges and Solutions for Mechatronic Systems and their Designers

Springer

Editors
Peter Hehenberger
Institute of Mechatronic Design
and Production
Johannes Kepler University Linz
Linz
Austria

David Bradley
School of Science, Engineering
and Technology
Abertay University
Dundee
UK

ISBN 978-3-319-32154-7 ISBN 978-3-319-32156-1 (eBook)
DOI 10.1007/978-3-319-32156-1

Library of Congress Control Number: 2016940131

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG Switzerland

Foreword

It is an honour and a pleasure to write a foreword for the Mechatronic Futures book cleverly devised and edited by Prof. David Bradley and Dr. Peter Hehenberger. This contribution is written on behalf of numerous colleagues in the UK and the wider world who have supported the Mechatronics Forum in its mission and activities. Founded in 1990, this forum was formed as an interest group in the UK and is currently sponsored by and part of the Institution of Mechanical Engineers (IMechE), London. Over the years since its formation, it has enabled professional engineers from industry and academia to share innovative ideas in this field and has acted as body to champion the discipline.

Mechatronics is a domain which spans most of my professional career and has been at the centre of fascinating technological developments and trends in the modern world. *Mechatronic Futures* reviews the origins of the discipline, explains the technological changes that have emerged and explores how mechatronics will further develop in future years, the challenges it will face and how it might need to respond in helping to address some of the grand challenges that are facing mankind.

The concept of mechatronic systems was first used in Japan in the 1960s by Tetsuro Mori to reflect the emerging role of electronic components used in the control and operation of what had previously been inherently mechanical systems. The Mechatronics Forum came into existence at a meeting held at IMechE's London headquarters on 30 October 1990, attended by over seventy engineers excited by an interest in the emerging discipline. It was the first organisation in the Western World that recognised the importance of mechatronics and began to promote it. Although the word mechatronics has been around since the late 1960s, it was only in the early 1990s that it was used to any great extent in the UK. However, during the 1990s, with the activities of the Mechatronics Forum, the term mechatronics and the engineering discipline that it encompasses became widely recognised.

Mechatronics today extends beyond the integration of mechanical, electronic and computer engineering. Many engineers now see it as embracing a wider range of engineering activities, from design through manufacture to the market place.

Hence, they regard mechatronics as a major influence in pulling together and integrating the many aspects of engineering which increased specialisation has tended to push apart from each other during the past decades. It was in an attempt to solve this increasingly challenging problem that the Mechatronics Forum was conceived as a first step towards the building of bridges between the many technologies, philosophies and disciplines which comprise mechatronics and the professional institutions that are committed to their own particular specialised subjects. In the UK, engineering institutions are important in sharing technical subjects between professionals in industry and academia. They accredit undergraduate and postgraduate courses as suitable for covering the academic components of a chartered engineer's development, and they grant Chartered status to those whose careers show sufficient engineering responsibility and understanding to be leaders in their field.

The Mechatronics Forum for its first ten years was supported under an inter-institutional arrangements, with secretarial and administrative services provided alternately by the Institution of Mechanical Engineers (IMechE) and the Institution of Engineering and Technology (lET). Following this, the Forum has been supported by the IMechE and linked with the Mechatronics, Informatics and Control Group (MICG).

The founding Committee of the Mechatronics Forum was charged with a broad remit including setting up and establishing a publication of a newsletter, popularising mechatronics, focusing on educational issues and seeking ways of bringing together all those interested in mechatronics, and especially of promoting closer links between industry and academia. Many of these are still the remit of the Forum today, and significant advances in a number of areas have been facilitated through the auspices of the Forum. The Mechatronics Forum Committee has included a number of members from outside the UK, to help with the internationalisation of the Forum and its activities as illustrated by most of the biennial international conferences being hosted outside the UK.

The original founding members of the Forum were Prof. Jack Dinsdale, the first chair of the organisation, Prof. Jim Hewit and Prof. David Bradley, each of whom were made Honorary Life Presidents of the organisation.

The showcase activity of the Mechatronics Forum since its formation has been the series of biennial international conferences, the first and longest standing conference on mechatronics in the world, featuring important contributions from around the globe. The very first conference was organised by Prof. David Bradley, whilst working at Lancaster University. The conferences have been an excellent means of sharing mechatronic ideas, thinking and applications more widely.

Hosts and venues for the fifteen conferences were:

1989: Lancaster University, UK
1990: Cambridge University, UK
1992: University of Dundee, Scotland, UK
1994: Technical University of Budapest, Hungary
1996: University of Minho, Portugal
1998: University of Skövde, Sweden

2000: Georgia Institute of Technology, Atlanta, USA
2002: University of Twente, The Netherlands
2004: Middle East Technical University, Ankara, Turkey
2006: Penn State University, Great Valley, Pennsylvania, USA
2008: University of Limerick, Ireland
2010: ETH, Zurich, Switzerland
2012: Johannes Kepler University, Linz, Austria
2014: University of Karlstad, Sweden
2016: Loughborough University, UK

Another highlight in the calendar of the Mechatronics Forum is the Prestige Lecture. Every year, an eminent speaker is invited to the headquarters of IMechE to deliver a topical and sometimes challenging lecture to the members. The following are some of the Prestige Lecturers to date:

- *The Role of Xero-Mechatronics in New Product Development*, Dr. John F. Elter, Xerox Corporation, April 1995
- *Advances in Mechatronics: the Finnish Perspective*, Vesa Salminan, FIMET, Finland, May 1996
- *The Industrial Benefits of Mechatronics: the Dutch Experience*, Prof. Job van Amerongen, University of Twente, the Netherlands, May 1997
- *Virtual Worlds—Real Applications: Industrial and Commercial Developments in the UK*, Prof. Bob Stone, University of Birmingham, May 1998
- *Mechatronics Solutions for Industry*, Prof. Rolf Isserman, University of Darmstadt, April 2000
- *Intelligent Mechatronics: Where to go*? Prof. Toshio Fukuda of Nayaga University, July 2001
- *Bionics: New Human Engineered Therapeutic Approaches to Disorders of the Nervous System*, Prof. Richard Norman, University of Utah, July 2003
- *GM's Approach to Eliminating Complexity and Making the Business More Successful*, Dr. Jeffrey D. Tew, General Motor's R&D Center, September 2004
- *Mechatronic Design Challenges in Space Robotics*, Dr. Cock Heemskerk and Dr. Marcel Ellenbroek, Dutch Space, June 2005
- *Cyborg Intelligence: Linking Human and Machine Brains*, Prof. Kevin Warwick, University of Reading, May 2006
- *Iterative Learning Control—From Hilbert Space to Robotics to Healthcare Engineering*, Prof. Eric Rogers, University of Southampton, March 2007
- *World Water Speed Record Challenge—The Quicksilver Project*, Nigel McKnight, Team Leader and Driver, Quicksilver (WSR) Ltd., May 2008
- *Meeting the Challenges and Opportunities of Sustainability through Mechatronics Product Developm*ent, Prof. Tim McAloone, Technical University of Denmark, Denmark, May 2009
- *I'm a Control Engineer: Ask me what I do*? Prof. Ian Postlewaithe, University of Northumbria, March 2010

- *Sports Technology: The Role Of Engineering In Advancing Sport*, Dr. Andy Harland, Sports Technology, Loughborough University, September 2011
- *Modelling, Control and Optimisation of Hybrid Vehicles*, Lino Guzzella, Swiss Federal Institute of Engineering, October 2013
- *The Past, Present and Future of Mechatronics: A Personal Perspective*, Professor Emeritus David Bradley, Abertay University, February 2015.

In addition to the biennial international conference series and the Prestige Lectures, the Forum has supported and facilitated many other activities related to mechatronics and its wider promotion including:

- Technical visits to industrial and academic organisations where these are open to members.
- Technical seminars and workshops focussed on particular aspects of the discipline.
- Mechatronics Student of the Year Award, a competition open to final-year degree students and master's level students based upon their final project dissertation.

To conclude the Mechatronics Forum is part of the Mechatronics, Informatics and Control Group of the Institution of Mechanical Engineers. It has had an important role in popularising mechatronics in the UK and, beyond, focusing on educational issues and promoting linkages between industry and academia, and seeking ways of bringing together all those interested in mechatronics.

Over the past twenty-five years or so, this has been encouraged through a variety of conferences, lectures, seminars, events and visits to industry and research centres. Mechatronics today is significant in industries worldwide. In our global environment, collaboration across the world is valuable in moving towards sustainable systems and solutions to societal challenges. The biennial conferences in particular have proven to be very fruitful in sharing ideas and stimulating debate between those at the forefront of mechatronics development which we hope will benefit societies across the world. Mechatronic future sets out a vision and narrative of how some of the future societal challenges might be addressed and the role mechatronics has to contribute to this.

Prof. Philip Moore
Falmouth University

Contents

Editors and Contributors

About the Editors

Peter Hehenberger is an assistant professor and deputy head at the Institute of Mechatronic Design and Production at the Johannes Kepler University of Linz (JKU) in Austria. He received his diploma degree and his doctorate degree in Mechatronics from JKU in 2000 and 2004, respectively.

His core competencies cover model-based mechatronic system design and include mechatronic design, systems engineering, design processes and model-based design methods. He has published over 70 peer-reviewed papers in international journals and conference proceedings and been guest editor for two journals' special issues. In addition, he has authored and co-authored 3 books related to the field.

He is presently a member of the Scientific Network of Linz Center of Mechatronics (LCM), Austria, and leads several international research projects related to the research area "*Process Modelling and Mechatronic Design*" at the LCM.

Peter Hehenberger is also one of the initiators of SmaPro,[1] a qualification network for the future challenges of Industry 4.0 together with 13 partners—four academic partners, four small and mid-sized companies as well as five large companies.

He lectures on the topics in product development, model-based systems engineering, mechanical engineering, mechatronic design, computer-aided design, simulation and manufacturing. He is currently co-supervising 6 doctoral students and 5 master theses by research students.

Among other scientific service activities, Peter Hehenberger organised the International Workshop Series on Mechatronic Design (Linz 2012, Paris 2013, Leuven 2014). He is also member of VDI, ASME, IFIP WG5.1 ("*Global Product development for the whole life-cycle*") and Design Society, where he co-chairs a Special Interest Group (SIG) on Methodologies for Design, Integration, Modelling and Simulation of Cyber Physical Systems.

[1]Smart Production: Machine data analysis and interpretation in production.

Between February and April 2015, he was an invited visiting professor at the Universite de Technologie de Compiegne, Departement Genie des Systemes Mecaniques, France.

David Bradley is currently professor emeritus at Abertay University. He began his academic career when he joined Lancaster University in 1972 and has been engaged with and involved in aspects of mechatronics since the mid-1980s and was responsible, with Prof. Jim Hewitt and Prof. Jack Dinsdale, for the establishment of the UK Mechatronics Forum, now the Mechatronics Forum.

In the course of a period of some 30 years at Lancaster University, the University of Wales Bangor and Abertay University, he has been involved in various aspects of the design, manufacture and operation of mechatronic systems for applications ranging from intelligent robots to medical and telecare systems and design methods. This included the establishment at Lancaster University in the late 1980s of some of the first mechatronics degree programmes, at both undergraduate and master's levels, in the UK as well the EPSRC-funded Engineering Design Centre which had mechatronics as a focus.

Most recently, he has been interested in exploring the interaction between mechatronics, the Internet of Things and Cyber-Physical Systems, and in particular how the design process can be adapted at both the systems and component levels to accommodate context-dependent systems elements derived from cloud-based technologies. This includes the means by which the design process enables the development of participatory systems structured around user need, essentially placing the user, who may be interested only in context, at the heart of the process of system integration, and including issues related to user privacy and security. He is also working in an advisory or consultative capacity with research groups in the UK and elsewhere on projects to develop advanced prostheses and evaluate mechatronics design methods.

A fellow of the Institution of Engineering and Technology (IET), David is the author, co-author or contributing editor for 7 textbooks, including 3 on mechatronics, some 50 journal papers and book chapters along with over 120 conference papers. He has also been responsible for the development of, and teaching on, mechatronics courses in the UK since the mid-1980s and has lectured on and acted as consultant for similar courses in, among others, the USA, Singapore, South Africa, Indonesia and Colombia.

Contributors

Nicolas Albarello is a researcher in the Systems Engineering Department of Airbus Group Innovations. He received his Ph.D. in Sciences for the Engineer from Ecole Centrale Paris in France. Since 2012, he has been contributing to several research projects in the field of systems engineering but also to operational projects for civil aircrafts and space systems. His main research topics include optimisation of systems (architecture, sizing, control), modelling and simulation, and decision aid in design.

Alexandre Arnold is a research engineer at Airbus Group Innovations in the Model-based System and Software Engineering team. He graduated in 2010 with a double diploma in engineering from the Ecole Centrale Lyon in France and the Technical University Munich in Germany, specialising in aeronautics and aerospace. He has since been working on various research projects, as well as operational projects for civil/military aircrafts and space division. The research topics have mainly been focused on MBSE, modelling and simulation, formal verification and systems of systems.

Jorge Azorín-López received a degree in Computer Engineering in 2001 and a Ph.D. degree in Computer Science at the University of Alicante (Spain) in 2007. Since 2001, he has been a faculty member of the Department of Computer Technology at the same university, where he is currently an associate professor and the deputy director of Research.

He was awarded the Post-doctoral Research Fellowship "*Automatic visual inspection of shape defects on specular surfaces. Methods to compensate low sensitivity of 3D image acquisition and reconstruction techniques*" by the Spanish Ministry of Science and Education for research at University of Edinburgh.

He has worked in 16 research projects and has published more than 50 papers on computer vision and computer architecture in several journals, conferences and book chapters. He has also served as a reviewer to numerous scientific journals and international conferences. Currently, he is associate editor of the IJCVIP journal. Current research interests include human behaviour analysis using computer vision, visual inspection and 3D modelling and analysis using computer vision.

Stefan Boschert graduated in physics from the University of Freiburg. After gaining his Ph.D. in 2000, he worked for an engineering company in Basel, Switzerland, on mechanical and hydro-dynamical modelling and simulation. Since 2004, he has worked at Siemens Corporate Technology in Munich, Germany, in the technology field of automation and control.

As a Senior Key Expert Engineer he is responsible for simulation-based system development, which includes multiphysics simulation, process models and integrated data and simulation model-based approaches. He has expertise in the set-up and implementation of mechatronic design processes and their extension to cyber-physical systems. Further, he was the manager of the department's contribution to several national and international publicly funded projects.

Jordan H. Boyle is a lecturer in the School of Mechanical Engineering, at the University of Leeds, and is also a founding member of the EPSRC National Facility for Innovative Robotic Systems, an advanced manufacturing facility. He obtained his B.Sc. and M.Sc. degrees in Electrical Engineering from the University of Cape Town, South Africa, before moving to the University of Leeds for a Ph.D. in Computational Neuroscience in the School of Computing.

Jordan's research lies on the interface of engineering and biology, and his main interest is in using biological inspiration to develop locomotion and navigation strategies for mobile intelligent robots. Since the phenomenal complexity of biological

systems makes it extremely challenging to decipher the mechanisms involved—a crucial first step in the biologically inspired design process—Jordan prefers to focus on relatively simple invertebrate systems. To date, his specific research projects have included developing a miniature mobile robot for use in colonoscopy and a snake-like robot controlled by a model of the C. elegans nervous system.

Robotics applications underlie Jordan's interest in advanced manufacturing. Indeed, one of the major barriers to the wider uptake of mobile autonomous robots is cost. If robots could be made cheaply and in large volumes, they would be deployed more widely, more frequently and in greater numbers.

Matthieu Bricogne is an assistant professor at the Mechanical Systems Engineering Department/Roberval Laboratory (UMR 7337) in Université de Technologie de Compiègne (UTC). He obtained his M.Sc. in Mechanical Engineering and a Mechanical Engineering Degree at UTC in 2004.

He has worked for 5 years for Dassault Systèmes, an industrially leading company specialising in 3D and Product Lifecycle Management (PLM) software. He obtained his Ph.D. degree in Mechanical Engineering from the Ecole de Technologie Supérieure in Montréal (ETS) and UTC in 2015. His main research topics are collaborative design, mechatronics system design and knowledge-based engineering within a PLM environment.

Since 2013, he has been vice-director of the ANR LabCom DIMEXP (DIgital MockUp multi-EXPertises) joint laboratory UTC/DeltaCAD, whose main objective is to develop methods and models to improve the integration of multidisciplinary expertises and heterogeneous data in advanced digital environments.

Marc Budinger is an alumni of the ENS Cachan (Paris) in Applied Physics, has a Ph.D. in Electrical Engineering (2003) and a HdR (habilitation) in mechanical engineering (2014) from Toulouse University.

Marc is an associate professor in the Mechanical Engineering Department of INSA Toulouse. His current research topic in the ICA laboratory concerns the model-based design of electromechanical and piezoelectric actuators and actuation systems. He is currently investigating the conjoint use of estimation/prediction models, 0D/1D simulation models, reliability models and metamodels from 3D FEM simulation for design and optimisation of mechatronics systems.

Benoît Eynard is currently the director of the Institute for Mechatronics at the Université de Technologie de Compiègne—UTC, France. In 2007 he joined UTC as a full professor, leading the Department of Mechanical Systems Engineering until 2012. He is also member of the UMR CNRS/UTC 7337 Roberval. Previously, he was an assistant professor at the Université de Technologie de Troyes where he managed the M.Sc. programme in Information Technology for Mechanical Engineering.

Since 2013, he has been general chairman of the academic group of French Society of Mechanical Engineering (AFM) dealing with factories of the future: integrated design and advanced manufacturing also known as AIP-PRIMECA network.

He is also a member of the IFIP Working Group 5.1 "*Global Product development for the whole life-cycle*" and of the Design Society where he currently leads the Special Interest Group on "*Design Methods for Cyber-Physical Systems*".

In 1999, he obtained a Ph.D. in Computer-Integrated Manufacturing from the University of Bordeaux. Now, he is a recognised researcher in product lifecycle management, collaborative design, systems engineering, mechatronic design, digital factory, manufacturing process management, eco-design and sustainable manufacturing. He has published over 50 papers in international journals and 150 international conferences. He also has been guest editor for 10 journal special issues and academic books.

Nicholas Fry is undertaking a Ph.D. research degree within the Leeds EPSRC National Facility for Innovative Robotic Systems, UK. He received his B.Eng. and M.Eng. degrees in Mechatronics and Robotics from the University of Leeds. Nicholas is researching advanced manufacturing techniques and has recently developed a novel 3D printing process, using industrial robotic arms, with the aim of autonomously embedding mechatronic components within rapidly fabricated structures.

Andres Fuster-Guillo received the B.S. degree in Computer Science Engineering from Polytechnic University of Valencia (Spain) in 1995 and the Ph.D. degree in Computer Science at the University of Alicante (Spain) in 2003.

Since 1997, he has been a member of the faculty of the Department of Computer Technology at the University of Alicante, where he is currently a professor. He has worked in more than 15 research projects and has published more than 40 papers on computer vision and computer architecture.

His current areas of research interest include vision systems to perceive under adverse conditions, 3D vision systems, automated visual inspection and artificial neural networks.

He was deputy coordinator of the Polytechnic School at the University of Alicante for seven years. Currently, he is director of the Secretariat for Information Technology at the University of Alicante, where he has coordinated and participated in several strategic technology projects: Open University (transparency portal and open data), UACloud, and Smart University, among others.

Thomas J. Howard is an associate professor at the Technical University of Denmark (DTU) after gaining his Ph.D. in Engineering Design from the University of Bath, UK. His main field of expertise is in robust design and more broadly engineering design research. He currently heads the robust design group at DTU and is the current chairman of the Design Society's Special Interest Group on Robust Design.

Tom has numerous past and present Ph.D. students and has attracted large amounts of research funding from both public and private sources including investment for the Novo Nordisk-DTU Robust Design Programme of around €1.5M. He sits as an elected member of the Design Society's advisory board and has received several accolades such as the DTU Innovation Prize 2014 and the BMW European Scientific Award. He has also published work in many top engineering design journals.

In addition to the research on robust design, Tom has a keen interest in innovation and technical entrepreneurship. He has been a keynote speaker at the European Innovation Academy several times and has been responsible and instrumental in numerous spinout companies.

Simeon Keates is professor and deputy pro-vice-chancellor of the Faculty of Engineering and Science at the University of Greenwich. He was formerly chair of HCI and head of School of Engineering, Computing and Applied Mathematics at Abertay University in Dundee and associate professor at the IT University of Copenhagen, where he lectured in the design and digital communication study line. He obtained his Ph.D. from the University of Cambridge, where he also worked as an Industrial Research Fellow in the Engineering Design Centre.

After leaving Cambridge, he moved to the USA and joined the Accessibility Research Group at the IBM TJ Watson Research Center before moving to Boston and working at ITA Software (now part of Google) as a usability lead designing interfaces for Air Canada. Simeon also has an extensive history of consultancy, with clients including the Post Office (Royal Mail), the US Social Security Administration, the UK Department of Trade and Industry, Danish Broadcasting Corporation (DR) and Lockheed Martin.

Antonio Lanzotti is the founding director of the Fraunhofer IDEAS (Interactive DEsign And SimulaTION) LABORATORY (www.ideas.unina.it) and is leading a research group on design methods at the University of Naples Federico II. He received his master's degree in Mechanical Engineering (summa cum laude) from Università degli Studi di Napoli Federico II in 1985.

From 1986 to 1987 he worked for the IT Department of Aeritalia. In 1990 he received a Ph.D. in Material and Production Technology from the University of Naples Federico II.

From 1992 to 1997, he undertook teaching and research activities at the Department of Aerospace Engineering as researcher and then from 1997 in a teaching position as associate professor. In 2001 he was appointed Full Professor in Design Methods of Industrial Engineering at University of Naples Federico II. He now teaches "*Product Design and Development*" and "*Engineering drawing*". He has been the only teacher of "*Statistics for Innovation*" not belonging to the "*Experimental Statistics for Engineering and Technology*" Scientific Sector.

He is associate editor in chief of the International Journal on Interactive Design and Manufacturing published by Springer. He is a reviewer for international journals, and he has been invited to lecture in international conferences and has promoted and organised many international conferences as a member of Steering and Scientific Committees. He was the President of the Italian Association of Product Design from 2004 to 2011. Further, he is the past president of the Italian Scientific Sector on Design Methods for Industrial Engineering (SSD ING-IND/15). Finally, he is responsible for the international agreement between the University of Naples Federico II and TU Chemnitz, ESTIA of Biarritz and University of Bartin, Turkey.

Julien Le Duigou is an associate professor at the Department of Mechanical Systems Engineering of Université de Technologie de Compiègne and researcher at Roberval Mechanical Laboratory (UMR CNRS 7337) and Labex MS2T "*Control of Technological Systems-of-Systems*" research centres. He obtained his mechanical engineering degree and his M.Sc. in Mechatronics in 2006 from Supmeca engineering

school and University of Toulon, respectively, and a Ph.D. in Mechanical Engineering in 2010 from Ecole Centrale engineering school.

He is also member of the IFIP working group 5.1 dealing with "*Global Product development for the whole life-cycle*" and of the IEEE Systems Man and Cybernetics Society. Currently, his research interests include product lifecycle management, knowledge management, interoperability and product/process integration. He published more than 50 papers in refereed international journals, books and conferences.

Craig Melville is a Ph.D. student studying in the Space Mechatronic Systems Technology Laboratory (SMeSTech) at the University of Strathclyde in Glasgow, having received his M.Eng. in Product Design Engineering in 2013 from the university's Department of Design, Manufacturing and Engineering Management (DMEM). His terrestrial design projects have involved a range of intra-discipline skills such as computer-aided design and simulation, structural analysis and design optimisation.

The projects he has been involved in allowed him to work with both Scottish SMEs and large international organisations; one project for Jaguar Land Rover allowed them to make design changes capable of saving up to £1,000,000 in assembly and manufacturing costs over 3 years.

Craig is currently focused on work relating to spacecraft and space robotic design for his Ph.D. studies, which he is due to finish in 2017. His work in the area focuses on the development of a design methodology for flexible use within space and complex design organisations. Other interesting realms of work include the design and optimisation of a multifunctional spacecraft interface, the development of universal interface design principles and the role of virtual reality and video games in conceptual/low TRL design phases.

Christopher Milne is associate chief information officer (Information Assurance and Governance) at the University of St. Andrews.

He gained a B.A. (Hons) in Librarianship and Information Studies at the Robert Gordon University (RGU) in 1994 before obtaining a PgDip in Information Analysis (1995). Following a spell as an IT trainer, Chris returned to RGU, where he was responsible for developing IT skills teaching in undergraduate and postgraduate modules.

In 1998, Chris joined the then University of Abertay Dundee, where he had a rich and varied career, predominately in the field of information management (academic librarian) and latterly as the officer responsible for corporate information and risk management across the university, as a Deputy Head of Information Services. Whilst at Abertay he read for a Masters in Records Management at Northumbria University (2007). He has published in the fields of information literacy—integrating core skills into the curriculum (2004), and records management—advocating the use of records management information retrieval philosophies as a means of improving access to information from corporate Websites (2007) and (2010).

In his current role at the University of St. Andrews, he is responsible for information governance and records management across the institution. He has a

business focused view of legislation and regulation—in that it should aid institutions in their mission and development and not hinder them via obsessive compliance and the introduction of unnecessary and/or artificial barriers. As part of the senior management team of the University's IT Services, he is also responsible for providing leadership and direction as IT Services emerges from a period of reorganisation. From 2015, he also gained responsibility for the day-to-day management of the university's complaint management function, developing organisational learning by assessing complaint contributory factors.

Aiguo Ming received the M.S. degree in Precision Engineering from Yamanashi University, Japan, in 1987, and the Ph.D. degree in Precision Machinery Engineering from the University of Tokyo, Japan, in 1990.

He is currently a professor in the Department of Mechanical Engineering and Intelligent Systems, The University of Electro-Communications, Tokyo, Japan. His current research interests include biomimetic hyper-dynamic robotics, biomimetic soft robotics, high-speed robotic hand systems with high-speed sensors, application of mobile manipulator systems and precise measuring mechatronic systems.

Philip Moore became pro-vice-chancellor (R&I) at Falmouth University in 2012. He leads all research and development, and is also chair of the Centre for Smart Design. Philip has been a visiting professor at University of Skövde, Sweden, since 1994 and on the Board of Directors of the Smart Home and Building Association (SH&BA). Phil was previously director of Research at De Montfort University (DMU) and director of the Mechatronics Research Centre and architect of the Intelligent Machines and Automation Systems (IMAS) laboratory. Phil studied Production Engineering and Management at Loughborough University whilst working in the automotive industry. He then studied for a Ph.D. in Robotics, whilst working in research at Loughborough, before joining as an academic member of staff, where he was a founder member of the Manufacturing Systems Integration (MSI) Research Institute.

Phil's own research focuses on smart digital technologies and their integration with sustainable design to address some of the societal grand challenges such as climate change, energy resilience, health and well-being and the ageing society. Other research interests include digital manufacturing and automation.

Phil was responsible for the founding of Digital Games at Falmouth and the associated research in computer games technology and was the architect of the successful European Research Area (ERA) Chair bid for €2.4 million to the FP7 programme in Digital Games research. Phil has supervised some 40 Ph.D. programmes to completion and has been external examiner on nearly 50 occasions.

Philip has won research funding from UK and EU agencies—EPSRC, ESRC, InnovateUK, EU FP, British Council, The Royal Society, RDA's and Industry. He has established a network of research collaborators in industry and academia in UK, Sweden, Germany and Italy.

Phil is vice-chair of Mechatronics, Informatics and Control Group, IMECHE, and chair of the Mechatronics Forum.

Stanislao Patalano is an associate professor in Design and Methods of Engineering Design at Department of Industrial Engineering, University of Naples Federico II.

He gained a master's degree in Mechanical Engineering in 1997, Ph.D. title in "*Machine Design and Construction*" in 2001, at the University of Naples Federico II. From 1999 until 2010, he was researcher in the Scientific Area of Design and Methods of Engineering Design. In 2006, he was visiting professor at the Institut Supérieur de Mécanique de Paris—SUPMECA, France, working on tolerance design.

He has published more than 90 papers in International Conference Proceedings, International Journals and National Journals. His research interests include CAD methodologies and knowledge-based engineering, variational analysis, tolerance design and design for assembly, and mechatronic systems design.

He has been member and coordinator of research groups within research projects funded by national public agencies (MIUR, Campania Region). From 2011 to 2014, he has been scientific responsible for the research activities of the Department of Industrial Engineering within "*PON Project 01_01268: Digital Pattern Development: a pattern driven approach for industrial product design, simulation and manufacturing*", in cooperation with FIAT Item, Fiat Chrysler Automobiles (FCA), Ansaldo-Breda, Ansaldo STS, SMEs (Technodesign, Tecnosistem, STEP Sud Mare).

He has scientific responsible for the COGITO (COmputer GeometrIc Modelling and SimulaTiOn) Laboratory at the Department of Industrial Engineering of the University of Naples Federico II. COGITO Laboratory is a part of IDEAS (Interactive DEsign And Simulation) Laboratory, established between University Federico II and Fraunhofer IWU.

He is currently professor of Geometric Modelling and Virtual Prototyping and Engineering Drawing at the University of Naples Federico II.

From 2012 to present, Promoter and Responsible for the University of Naples Federico II of the Academic Course aimed to a double master's degree: "*Master Degree in Mechanical Engineering for Designing and Manufacturing*" and "*Diplôme d'Ingénieur Supméca*".

Rob Richardson is professor of Robotics at the School of Mechanical Engineering, University of Leeds, UK, and a fellow of the IMechE. He is director of the Leeds EPSRC National Facility for Innovative Robotic Systems, a world class, facility for designing and creating robotic systems initiated in August 2013. He is also director of the Institute of Design, Robotics and Optimisation at the School of Mechanical Engineering. He is co-director of the UK EPSRC cities grand challenge, awarded in November 2015 with the aim of using robotics to perform minimally invasive infrastructure repair.

He held a prestigious research contract to explore the Great Pyramid of Giza, Egypt, using robotic technology and has discovered writing in the Great Pyramid that was hidden for thousands of years.

His current research interests focus around the fabrication of complex robotic systems with application to exploration robotics for safety and security including: inspection and repair of city infrastructure; protecting life by accessing confined

spaces to find survivors of natural disasters; gathering information on terrorist and military threats; inspecting inaccessible industrial plants; or processes utilising enhanced sensing and networking.

Roland Rosen studied mathematics with a minor in economics at the Technical University of Munich. After joining Siemens in 1989, he worked in different positions in the area of modelling, simulation and optimisation of technical systems, plants and infrastructure solutions. Currently, he is at Siemens Corporate Technology as a Principal Key Expert Research Scientist responsible for the international focus area of modelling and simulation.

He is involved in different activities related to "Industrie 4.0", and he is a member of expert committees of VDI/VDE Society for Measurement and Automatic Control (GMA). Roland Rosen works on the realisation of simulation-based methods for mechatronic systems and complex plants. His specific interest is in the seamless integration of simulation into all lifecycle phases of system development and the use and reuse of simulation models and technologies during operation and services.

David Russell was awarded his Ph.D. in recognition of his research at the UK Atomic Energy, the University of Manchester and the then Liverpool Polytechnic. His thesis included the design of an intelligent controller for a novel fast reactor using a fluidic control schema.

Dr. Russell is a professor of engineering at Penn State Great Valley where has spent the last 30 years. Dr. Russell was past chair of the campus IT Advisory Board and was a founder member of the University Committee for Enterprise Integration, which is part of the SAP University Alliance programme. Whilst senior division head for fourteen years, Professor Russell designed and implemented two professional postgraduate degrees in Software Engineering and Systems Engineering which are now available on-campus and online.

He has taught at the undergraduate and post graduate level in the UK, USA and Asia over the past half-century and has created, managed and taught systems engineering, information technology and computer engineering activities including scholarly and professional international conferences. He has delivered invited and plenary lectures in over thirty countries. Dr. Russell serves the editor for the Americas for the International Journal of Advanced Manufacturing Technology, a Springer publication.

Dr. Russell is a past fellow of the Institute of Electrical Engineering and fellow of the BCS (British Computer Society) and a current fellow of the Institute of Mechanical Engineers (IMechE) and a Chartered Engineer.

Prior to Penn State Dr. Russell held several positions as a technical executive with factory systems integration companies in the USA and the UK and has held several faculty appointments in other universities. He is the author over 120 technical papers and an active international member of the Mechatronics Forum, an IMechE scholarly society.

Marcelo Saval-Calvo received the degree in Computer Engineering in 2010 and the M.Sc. in 2011 from the University of Alicante (Spain) with a master's thesis in the area of computer vision. He received his Ph.D. in 2015 from the University of Alicante focused on 3D registration of rigid and deformable subjects.

He is currently working in the Computer Technology Department at the same university. He was awarded a research fellowship by Regional Ministry of Education, Culture and Sports of Valencian Government for researching at the University of Edinburgh. His current research interests include human behaviour analysis using computer vision, 3D registration of rigid and deformable data.

Maarten Steinbuch is distinguished university professor at Eindhoven University of Technology. He received the M.Sc. degree and Ph.D. degree from Delft University of Technology, in 1984 and 1989, respectively. From 1987 to 1998, he was with Philips Research Laboratories in Eindhoven as a Member of the Scientific Staff. From 1998 to 1999 he was manager of the Dynamics and Control Group at Philips Center for Manufacturing Technology.

Since 1999, he has been full professor and chair of the Control Systems Technology Group of the Mechanical Engineering Department of Eindhoven University of Technology.

He has been editor in chief of IFAC Mechatronics (2009–2015), scientific director of the Research Centre High Tech Systems of the Federation of Dutch Technical Universities, director of the TU/e Graduate Program Automotive Systems, initiator of the TU/e Bachelor Automotive, member of the board of AutomotiveNL, member of the Formule E team, member of the advisory board of the High Tech Institute and of Nobleo Technology BV, co-founder of MI-Partners BV, co-founder of Mechatronics Academy BV, co-founder of Preceyes BV and founder of Steinbuch in Motion BV. He is CEO of Medical Robotics Technology BV.

Since 2014, he is also the scientific director of the new TU/e High Tech Systems Center HTSC. In 2003, 2005, 2008 and 2015, he obtained the "Best-Teacher" award of the Department of Mechanical Engineering, TU/e. In 2008 as well as in 2014, his research group obtained the QANU excellence rating [5555]. In 2013 he was appointed distinguished university professor at TU/e. In 2015 Maarten received the KIVI Academic Society Award. His research interests are modelling, design and control of motion systems, robotics, automotive powertrains and of fusion plasmas.

Jonas Mørkeberg Torry-Smith has been involved in design of mechatronic systems for more than a decade performing research within the field as well as carrying out mechatronic product development in industry.

He holds a Ph.D. in systematic design of mechatronic products. The research has been aimed at procedures for mechatronic development integrating the mechanical, the electronics and the software engineering discipline. The research also comprises proposals for methods for modelling mechatronic concepts across the disciplines elucidating central conceptual dependencies.

From 2002 to 2014 Jonas Torry-Smith was affiliated to IPU—a consulting company—working with mechanical and mechatronic development as a consultant for Danish and international companies. The range of projects comprises

innovation projects, concept scouting as well as total turn-key projects. The projects have been carried out as project manager, team member or as specialist. In addition, on-the-job training has been performed for international companies based in Denmark. He has recently switched to the Pharma industry working for a large international med-tech company.

Steve Watt is chief information officer at the University of St. Andrews. A native of Scotland he was born in Dundee in 1971 and currently lives north of Dundee in the county of Angus.

Steve was educated at the then University of Abertay Dundee where he gained a Bachelor of Science degree in Building Engineering and Management, a Master of Science degree in Information Technology and later a Master of Business Administration degree.

Steve is a European engineer, chartered engineer, chartered IT professional and a fellow of the British Computer Society and has 20 years' experience working within the information technology field.

He has worked primarily in the Higher Education sector in a variety of roles which have included Network Analyst, IT Manager, Deputy Head of Information Services and Chief Information Officer (CIO).

Steve has also worked in the private sector for Low & Bonar plc in both Europe and North America. In this role, he was responsible for the coordination and delivery of corporate IT provision at around 52 locations which included the provisioning and management of wide area networking, telecommunications, groupware and systems management working with outsourced partners centralising the core ICT support for all sites to the UK. He has also worked as a consultant across a range of industries.

In his current role as CIO at the University of St. Andrews, he is responsible for the IT services and change management functions comprising of around 90 staff and is a member of the University Senior Management Team. He is responsible for the strategic development of all IT provision, information assurance and governance and business transformation activities.

He is a member of the Board of Management of Dundee and Angus College, chair of the Higher Education IT Directors in Scotland Group and a member of the Scottish Government Technical and Design Board. Steve is a frequent contributor at IT conferences including as conference chair and panellist.

George R. S. Weir is a lecturer in Computer and Information Sciences at the University of Strathclyde in Glasgow, Scotland. He holds academic qualifications from three Scottish universities, including a Ph.D. from the University of Edinburgh. In addition to teaching and research supervision, he has published extensively in the areas of cybercrime, security, readability and corpus linguistics.

He is a member of the BCS Forensics and Cybercrime Specialist Group, the Association of Computing Machinery, the British Computer Society and the Higher Education Academy. He is also a senior member of the IEEE and a fellow of the Winston Churchill Memorial Trust and a fellow of the Royal Society of Arts.

Xiu-Tian Yan is professor in Mechatronic Systems Technology, the director of the Space Mechatronic Systems Technology Laboratory (SMeSTech) and deputy director of Strathclyde Space Institute, based in the Department of Design, Manufacture and Engineering Management (DMEM) of the University of Strathclyde. He is the vice-chairman of the Mechatronics Forum in the UK and chairman of the Robotics and Mechatronics Technical Professional Network of the Institution of Engineering and Technology.

Through over 30 years' work and investigation, he has developed a portfolio of research projects in mechatronic system design research including the development and application of "*mechatronic design process models*", modelling and simulation of these systems, and techniques in prototyping these systems for validation. He has recently built a strong research team after establishing SMeSTech research laboratory in 2012. He has managed over 40 projects in his research fields funded by the UK government funding bodies (EPSRC, TSB/InnovateUK, STFC), European Commission, international funding bodies and industrial partners.

He received his Ph.D. from Loughborough University of Technology and is a chartered engineer and a fellow of Institution of Engineering and Technology (formerly IEE) and a fellow of IMechE. His research interests include mechatronic systems design, robotics especially in recent years in space robotics, *Micro-mechatronic research and multi-perspective mechatronic system modelling, design and simulation,* computer support mechatronic systems design using AI techniques, knowledge-intensive product modelling and simulation, *the proactive computer support of product life-cycle synthesis* and *Product generalisation and configuration design and constraint based insightful engineering design support*.

He has organised and chaired four international conferences and published over 180 technical papers in major international journals and conferences and edited or written 6 books in related fields. He is an invited professor or visiting professor at 4 international universities, and he has been invited to give lectures at French, Japanese and Chinese Universities and various research institutions. He is the recipient of Judges Commendation Best KTP Partnership (Scotland) 2010 award and several best paper awards. He has also been a key team member for several industry best awards for some mechatronic products and systems.

Wenjing Zhao received the B.S. degree and M.S. degree (Mechatronics Engineering) from the University of Electronic Science and Technology of China in 2007 and 2010, respectively. She received her Ph.D. degree at the Department of Mechanical Engineering and Intelligent Systems from The University of Electro-Communications in Japan at 2014.

During the Ph.D., her research was primarily focused on the development of biomimetic soft underwater robots. She now is working at the College of Mechanical Engineering in the Zhejiang University of Technology in China. Her current research interests include soft robots, mechatronics, fluid–structure interaction system, friction and sealing, and other robotic technologies.

Chapter 1
Mechatronic Futures

David Bradley and Peter Hehenberger

1.1 The Challenge

The period of over 40 years since the concept of a mechatronic system was introduced by Tetsuro Mori [1] to express the growing impact that the availability of electronic components was having on the control and operation of inherently mechanical systems has been, and continues to be, a period of significant and rapid technological change. In particular, there has been a shift in emphasis within systems from hardware to firmware and software, leading to the introduction of a wide range of consumer products structured around the use of smart devices, many of which remain essentially mechatronic in nature in that they bring together a core of mechanical engineering with increasingly sophisticated electronics and software. When combined with enhanced local and remote communications, this has led to the evolution of systems based around the ability of smart objects to communicate with each other, and hence to effectively self-configure according to context.

This in turn has led to the development of concepts such as Cyber-Physical Systems, the Internet of Things and Big Data [2–11] in which interaction is driven through the combination of smart objects and information. Referring to Figs. 1.1, 1.2 and Table 1.1, users access cloud-based structures through smart objects to draw on resources provided by a range of, often unknown or invisible, sources.

The growth of provision represented by Table 1.1 has also led to a growth in availability of sophisticated user systems where, for instance, smartphones increasingly incorporate high-quality still and video imaging capability to the point where they are now responsible for more images than conventional cameras. It has

D. Bradley (✉)
Abertay University, Dundee, UK
e-mail: dabonipad@gmail.com

P. Hehenberger
Johannes Kepler University Linz, Linz, Austria
e-mail: peter.hehenberger@jku.at

P. Hehenberger and D. Bradley (eds.), *Mechatronic Futures*,
DOI 10.1007/978-3-319-32156-1_1

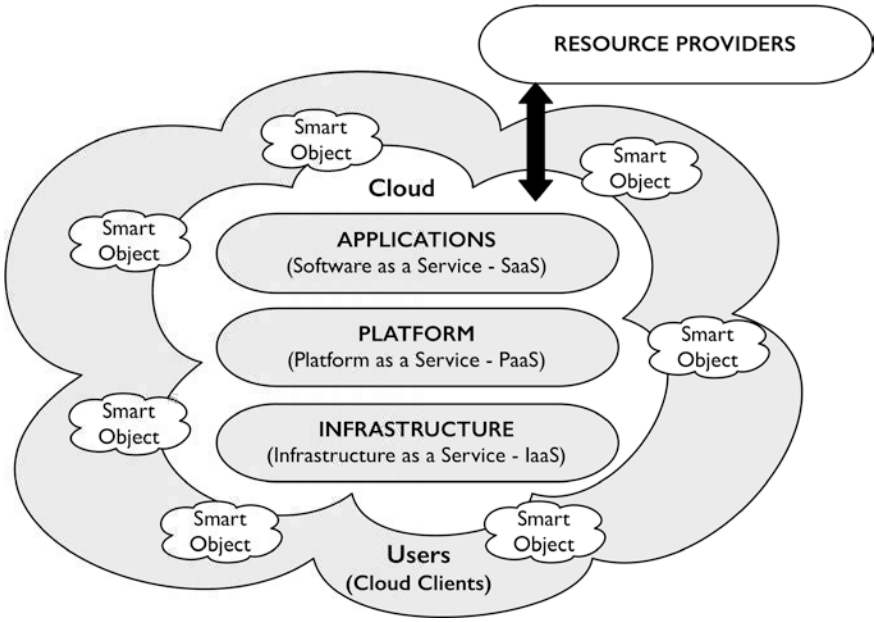

Fig. 1.1 Cloud-based structures for the Internet of Things

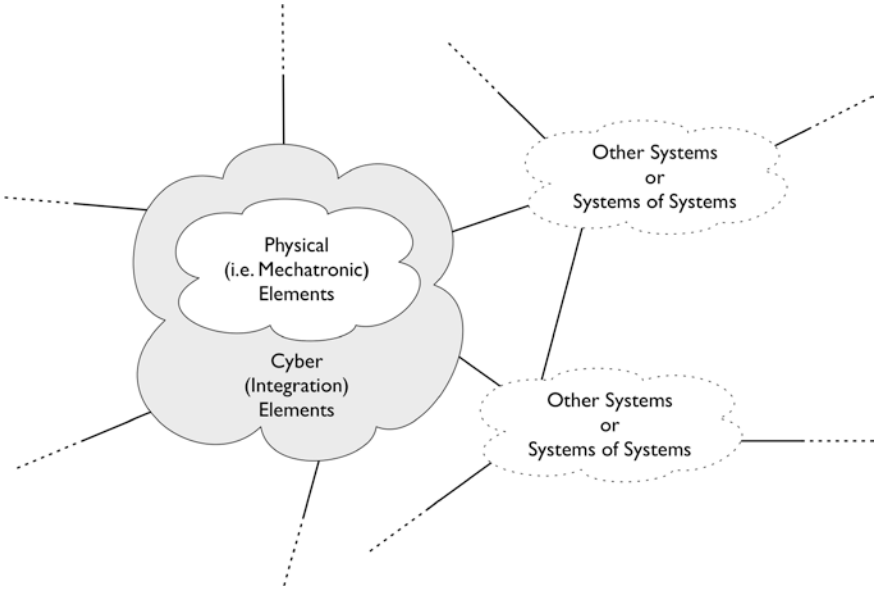

Fig. 1.2 Cyber-physical systems

Table 1.1 Cloud functions

Applications (software as a Service—SaaS)	Apps, Games, Mail, Virtual Desktop, Customer Management, Communications, Access, On-Demand Systems, …
Platform (platform as a Service—PaaS)	Runtime Operation and Management, Databases, Web Server, Tools, Computation, …
Infrastructure (infrastructure as a Service—IaaS)	Virtual Machines, Servers, Storage, Load Balancing, Networking, Communications, …

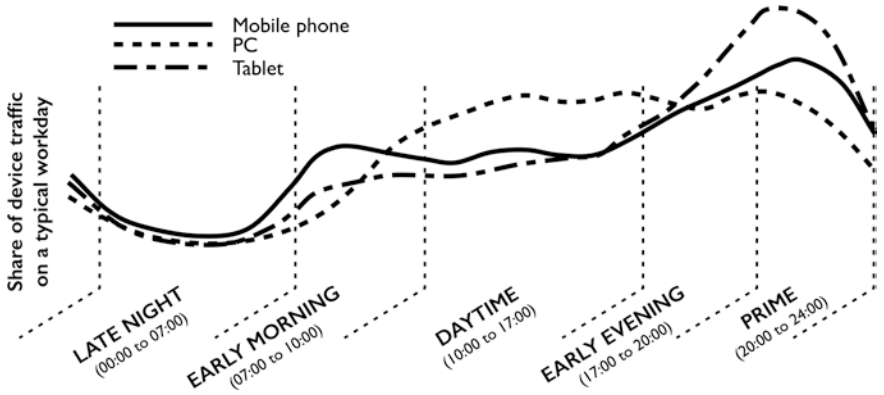

Fig. 1.3 Daily profile of use for mobile phones, PCs and tablets (after [12])

also led to the introduction of a range of user devices for behavioural monitoring, smart watches and tablet computers, all of which are capable of interacting with other smart devices through the medium of the Internet. Figures 1.3 and 1.4 together illustrate the daily profile of use for such devices [12–15]. All of the above have implications for the design, development and implementation of mechatronic systems, and for the future of mechatronics itself [16, 17].

In 2014, in association with the Mechatronics Forum Conference held in Karlstad in Sweden, a number of practitioners from around the world were asked to provide, in a single phrase, their view of the most significant challenges faced by mechatronics in coming years. The responses received are presented as Fig. 1.5 and will be discussed in more detail in the following sections of this chapter.

1.2 Challenges

Taking the above responses, the key issues can be summarised as:

- Design
- Privacy and Security

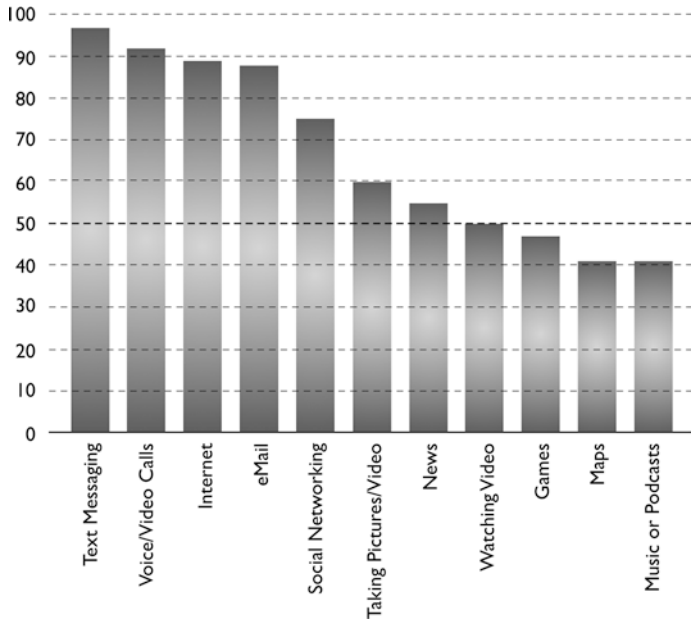

Fig. 1.4 Mobile phone use (after [13])

- Complexity and Ethics
- Ageing Population
- Users
- Sustainability
- Education

Each of which will be briefly discussed in the following sections.

1.2.1 Design

Conventional approaches to engineering design typically follow a path such as that defined by the simplified V-Model of Fig. 1.6 with integration being achieved through a structured system definition followed by a process of system development supported by appropriate testing regimes to support verification and validation. Individual modules and sub-modules, including those from external sources, are then tied into the design by a process of specification, test, verification and validation to ensure overall system functionality.

This approach has evolved over many years through the synergetic interaction between design theory and design practice. However, it is the case that design theory must inevitably lag behind practice where the possibilities afforded by new

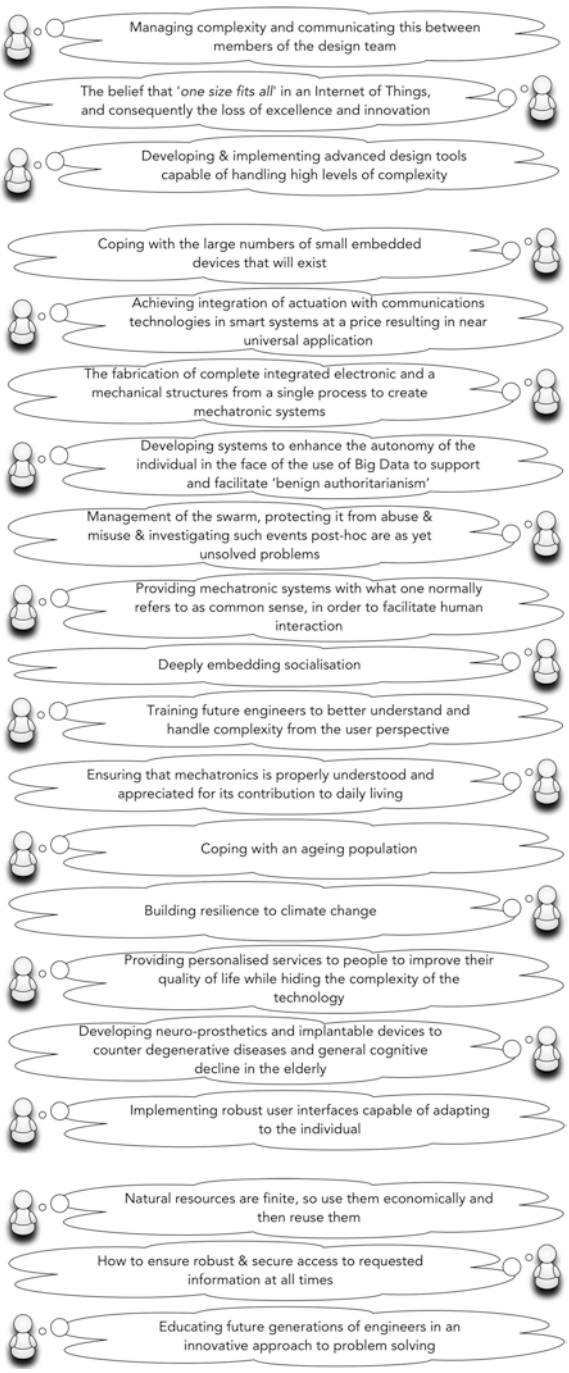

Fig. 1.5 Practitioner responses regarding challenges facing mechatronics